Reforming LIBOR and Other Financial-Market Benchmarks*

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Abstract: We outline key steps necessary to reform the London Interbank Offered Rate (LIBOR) so as to improve its robustness to manipulation. We first discuss the role of financial benchmarks such as LIBOR in promoting over-the-counter market efficiency by improving transparency. We then describe how to mitigate LIBOR manipulation incentives by: (i) widening the types of transactions used to fix LIBOR; and (ii) encouraging a transition of "rates trading" applications of LIBOR derivatives to alternative reference rates that are in principle more suitable for this purpose because they do not include the bank-credit-spread component inherent in LIBOR. The current exceptional depth and liquidity of LIBOR-based markets are self-fulfilling sources of dominance for LIBOR as the reference rate of choice among rates traders. This liquidity agglomeration around LIBOR is probably accidental and inefficient, and creates an incentive to manipulate LIBOR. A transition of rates trading to alternative reference rates, however, may be difficult to arrange without official-sector involvement.

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1. Introduction

Benchmarks such as LIBOR play a central role in modern financial markets. LIBOR is the London Interbank Offered Rate: a measure of the rate at which large banks can borrow from one another on an unsecured basis. In its current form, LIBOR is determined each day (or "fixed"), not based on actual transactions between banks but rather on a poll of a group of panel banks, each of which is asked to make a judgmental estimate of the rate at which it could borrow. The daily LIBOR fixing is in turn used to set the interest rates that consumers and businesses pay on trillions of dollars in floating-rate loans. Investors also rely on the difference between LIBOR and risk-free interest rates as a gauge of stress in the banking system. Revelations of widespread manipulation of LIBOR and other benchmarks, including those for foreign exchange rates and some commodity prices, have threatened the integrity of these benchmarks and lowered trust in financial markets more generally.

The two of us recently contributed to a pair of reports commissioned by the Financial Stability Board that recommend how to make reference rates such as LIBOR, EURIBOR, and TIBOR (collectively, the "IBORs") less vulnerable to manipulation.[1] While these reports cover many technical issues, they are based on two overarching principles.

First, benchmarks like these should be based—to the greatest practical extent—not on judgments submitted by market participants, but on actual transactions. Anchoring benchmarks in transactions is a key recommendation of several previous policy groups.[2] But a tough problem confronts a shift to transaction-based IBOR benchmarks. As just noted, the 'I' in IBOR stands for "interbank." The daily fixing of LIBOR is supposed to be an estimate of the rate at which

[1] These reports are Market Participants Group on Reference Rate Reform (2014) and Official Sector Steering Group (2014).

[2] See, in particular, International Organization of Securities Commissions (2013).

major banks can borrow *from each other*. Unfortunately, there are surprisingly few actual loan transactions between banks that could be used to fix most of the IBORs, including those for the hugely popular 3-month and 6-month maturities. The thinness of the underlying interbank markets has made it difficult to come up with reliable daily fixings that are transactions-based.

The solution proposed in our groups' policy reports is to fix the IBORs using a much wider set of unsecured bank-borrowing transactions, not just those in the interbank market. This approach would include wholesale certificates of deposit as well as commercial paper issued by banks to a wide range of non-bank investors.

Second, and crucially, the reform process should strongly encourage heavier use of alternative benchmark reference rates. The IBORs are currently used for a range of applications going well beyond their original purpose, which is to price loans at a markup over average bank borrowing costs, including a spread component for bank credit risk. Particularly with the enormous boom in interest-rate derivatives trading since the 1980s, IBORs have been heavily used in contracts whose purpose is to transfer risk related to general market-wide interest rates. These "rates trading" applications are not specifically tied to the borrowing costs of banks. It is a self-reinforcing choice by market participants, however, to trade in more liquid high-volume markets, all else equal. In part through an accident of history, this desire to belong to the high-liquidity club has led to a massive agglomeration of trade based on the IBOR benchmarks.

While such an agglomeration effect is beneficial from the standpoint of liquidity, it increases incentives for market manipulation. The deep and liquid IBOR-based derivatives markets can accommodate extremely large derivatives positions. And a trader with a sufficiently large position can profit significantly from even tiny distortions in IBOR fixings, on the order of one basis point (0.01%). Until now, manipulators have arranged for dishonest judgment-based

reports of bank borrowing rates. With a transactions-based benchmark, a manipulator might attempt to distort actual transactions. Either way, the message is the same: A thin underlying bank borrowing market cannot be a robust foundation for a multi-hundred-trillion dollar derivatives "rates" market, even with substantial improvements to the IBOR fixing methodology.

Fortunately, many of the rates trading applications currently served by the IBORs could be as well or better served by risk-free or near-risk-free benchmarks that are not tied to banks' costs of funds. In the U.S., for example, Treasury bill or general-collateral repo rates would be adequate or preferred for many rates-trading applications.

We do not underestimate the difficulty of getting market participants to opt for alternative reference rates so long as IBOR-based markets are so liquid. Precisely because everybody prefers to be in the high-liquidity club, there is a coordination problem. No individual actor may be willing to switch to an alternative benchmark, even if a world in which many switched would be less vulnerable to manipulation and offer investors a menu of reference rates with a better fit for purpose. Hence, there may be an important role for policymakers to guide markets in the desired direction.

The remainder of this paper is organized as follows. Section 2 discusses the economic role of benchmarks in reducing market frictions, explains how manipulation occurs in practice, and illustrates how benchmark definitions and fixing methods can mitigate manipulation. Section 3 suggests an overall policy approach for reducing the susceptibility of LIBOR to manipulation. Section 4 considers how to make an orderly transition to alternative reference rates, without raising undue legal risks. Section 5 briefly concludes.

2. The Basic Economics of Benchmarks

A. Why use benchmarks?

Financial market participants rely on benchmarks for a range of purposes that are primarily related to reducing asymmetric information regarding the value of the underlying traded financial instrument.

Consider for illustration a forward contract for gold, committing a buyer to pay the difference between the agreed forward price and the spot price of gold at the future contract settlement date.[3] Without recourse at the time of settlement to an independently announced gold price benchmark, the counterparties could easily disagree about the net payment due. Indeed, they have precisely opposite incentives regarding how to measure the spot price of gold. As a result, they could expend extra effort to settle their contract, or might have contracted instead on the basis of a more costly (but less manipulation-prone) physical-delivery settlement method, or in light of anticipated settlement costs they might even have failed to agree on a contract in the first place, thus losing their gain from trade entirely. Even if a benchmark exists, these costs may arise to the extent that the benchmark is not reliably measured, especially through manipulation. Clearly, if one of the counterparties to a trade also plays a role in the fixing method that determines the announced benchmark price, the incentive to manipulate is especially severe. This moral hazard may lead to lower market participation or even a market breakdown.

Reliable benchmarks also reduce search costs in over-the-counter markets, where they can improve matching efficiency and increase participation by less informed agents. For example, with the publication of a benchmark such as LIBOR, bank customers are better able to judge whether a loan rate is competitive. Without a benchmark, intermediaries can take greater

[3] There have been recent allegations of manipulation of gold benchmarks. See Vaughn (2014).

advantage of market opaqueness and of the cost to customers of searching for alternative quotes.[4] This idea has been modeled by Duffie, Dworczak, and Zhu (2014), who provide conditions under which the publication of a benchmark can lower total search costs and improve the competitiveness of quotes. The resulting reduction in profit margins for financial intermediaries can potentially be more than offset through increased volume of trade. Thus, it may be to the advantage of intermediaries to introduce a benchmark. For example, in 1969 a consortium of London-based banks led by Manufacturers Hanover introduced LIBOR in order to entice international borrowers such as the Shah of Iran to borrow from them.[5] By 1984, LIBOR became an official benchmark of the British Bankers Association.

A further transparency benefit of benchmarks applies when investors delegate their trading decisions to agents, who may not make best efforts to obtain good trade execution on behalf of their clients. Suppose an investor selling Euros for dollars is told by her broker, "We obtained an excellent price of $1.3500 for your Euros." Absent a benchmark, the investor could not easily validate the broker's claim, and may be suspicious of the potential for dishonest service, such as front running. If, however, there is a nearly simultaneous published benchmark fixing for Euros of $1.3501, then the broker's claim of good execution is easily verified. Less informed investors who delegate their trade execution to agents are thus more willing to participate in markets when incentives for good execution are supported by the existence of reliable benchmarks. The recent report of the Financial Stability Board (FSB) on foreign

[4] Before the advent of LIBOR in the United States, banks commonly quoted variable-rate loans at some spread above a "prime rate," but there was no official fixing of "prime." Each bank decided on its own prime rate, and while these rates moved in relatively close tandem across banks, more sophisticated borrowers understood the benefit of shopping around.

[5] For a brief history, see Ridley and Jones (2012). Other motives for this introduction of Libor may have included the potential for limiting competition by lenders who were not part of the Libor consortium, and as a method for negotiating, within the consortium, a syndicating loan rate.

exchange (FX) benchmarks confirms that the least sophisticated investors are the most likely to prefer that their FX trades be executed at the precise time at which the benchmark is fixed.[6]

In the special case of IBORs, there is an important additional motive for introducing a benchmark. Suppose a bank wishes to hedge the risk of a change in its borrowing cost, but has private information about its idiosyncratic credit quality. The resulting adverse selection may make it hard to negotiate a contract that is based on its own future credit spread. This market breakdown might be overcome with hedging contracts that are instead linked to market-wide, rather than bank-specific, credit spreads. In this case, a benchmark such as an IBOR allows banks to hedge at least the common component of their borrowing costs.

B. Agglomeration of trade around benchmarks

Once a benchmark has been established, it can become a powerful "basin of attraction" for related trades, based on two types of agglomeration effects. To see why, suppose there is a spectrum of possible non-benchmark trades that could be substituted with a benchmark trade. These alternative types of trades are differentiated by their risk attributes and other characteristics, such as time of execution (relative to the time at which the benchmark is fixed).

One force driving agglomeration is the incentive for market participants to reap the information-related benefits of a benchmark that we described in the previous section, including lower search costs, higher market participation, better matching efficiency, and lower moral hazard in delegated execution. In order to obtain these benefits, market participants or their

[6] See Foreign Exchange Benchmark Group (2014). Indeed, less sophisticated investors in FX markets commonly request "fix trades," by which they contract with a dealer to buy or sell at the benchmark price itself, without a fee or bid-ask spread. The dealer absorbs the risk of laying off the position acquired from its clients at a different price, and thus a potential loss. The dealer may be compensated in part, however, by the common practice in this market of front running by dealers, who may trade on their own behalf a few seconds before the fixing, thus causing a price impact to the fixing that can benefit the dealer at the expense of its clients. Whether malicious or not, the report commissioned by the Financial Stability Board recommends that this practice be curtailed.

agents will often choose to substitute their "best-fit-for-purpose" trade with a benchmark trade. For example, a foreign-exchange trade that, absent benchmark effects, would optimally be executed at 5pm London time could be shifted to the standard 4pm fixing time of the extremely popular WMR benchmark. Similarly, an investor who is interested in taking a hedging or speculative position in risk-free interest rates might shift toward a LIBOR-based financial instrument, even if the bank-credit-spread component of LIBOR is somewhat undesirable. If there are multiple benchmarks, there can be a substitution toward instruments that reference the most transparent of these benchmarks.

The second force of agglomeration is the incentive to lower trading costs that are associated with illiquidity. A high volume of trade in a financial instrument is typically associated with a smaller bid-ask spread, shorter execution delays, lower search costs, and a lower price impact for large trades. Once trading in a benchmark-related instrument is active, there is an incentive to substitute from less-actively traded instruments toward instruments that reference the benchmark.[7] This liquidity incentive can easily dominate the mildly undesirable investment characteristics of a benchmark instrument.

The basin of attraction of a benchmark can thus become larger and larger, given the positive feedback effects of informational transparency and liquidity. In the next section, we provide some statistics that illustrate the extent to which LIBOR has become the overwhelmingly popular interest-rate benchmark.

Once LIBOR liquidity became firmly established in the 1980s, dealers and derivatives exchanges had the incentive to introduce a wide range of LIBOR-based hedging instruments,

[7] See McCauley (2001).

particularly options of various types.[8] The availability of risk transfer in these related instruments further increased the magnetic qualities of LIBOR-based trading.

C. Manipulation and manipulation-resistant fixing methods

During the financial crisis of 2007-2009, there was a special incentive for banks to misrepresent their borrowing costs. Some banks did not wish to appear to be less creditworthy than others, in order to avoid creating concerns that might have raised their costs of funding, or in the extreme case, caused a run. The rates reported by each of the panel of banks polled to produce LIBOR were quickly published, alongside the name of the reporting bank, for all to see. As a result, there arose at some banks a practice of "low-balling," that is, understating true borrowing costs when submitting to a LIBOR poll. The unrealistically tight bunching among banks of their reported borrowing rates lead to news reports of likely manipulation.[9] Subsequent research revealed a substantial downward and persistent bias in LIBOR fixings relative to actual bank borrowing rates.[10] This was a "Lake Wobegon" effect, by which all banks were anxious to appear to be at least as creditworthy as the average reporting bank.[11]

The second basic motive for manipulating benchmarks is generic: a desire to profit on positions in instruments that are contractually linked to the benchmark. In the case of IBORs, some derivatives traders asked bank officials that were charged with providing rate submissions

[8] The LIBOR-related derivatives include CME Eurodollar futures and options, and OTC-traded caps, floors, swaptions, and other volatility-related derivatives.

[9] See Mollenkamp (2008) and Mollenkamp and Whitehouse(2008).

[10] See Abrantes-Metz, Kraten, Metz and Seow (2012), Snider and Youle (2012); and Kuo, Skeie, and Vickery (2012). For an overview, see Hou and Skeie (2013).

[11] See Garrison Keillor at http://www.publicradio.org/columns/prairiehome/posthost/2013/04/01/the_lake_wobegon_effect.php

to the IBOR poll to bias their reports.[12] Sometimes these requests would be relayed by another trader, often located at another bank. In some instances, more significant distortions in an IBOR were achieved through collusion that coordinated the misreporting among several banks.

Clearly, if traders are able to benefit their swap positions by causing a benchmark fixing to move one way or the other, the least ethical of them may attempt to do so. The ease with which a fixing can be distorted will always be a source of incentive to manipulate. However, an additional incentive is the ease with which very large positions in IBOR-linked derivatives can be established, given the extremely high volumes and liquidity in this market.

In order to mitigate manipulation, tighter governance and regulatory monitoring of the fixing process may be somewhat effective, especially for those benchmarks that are set by judgment-based reporting.[13] But the first line of defense is a benchmark definition and a fixing methodology that are simply difficult to manipulate.

All else equal, it is better to have a large set of transactions determine the benchmark fixing, so that it is difficult for manipulated trades or reports to have much influence on the fixing, and so that it is easier to detect when trades and reports are distortionary. This can be achieved in part by widening the time window over which rates or prices are averaged to

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[12] The CFTC investigation of Barclays revealed the following emails or text messages from swaps traders: 1) "WE HAVE TO GET KICKED OUT OF THE FIXINGS TOMORROW!! We need a 4.17 fix in 1m (low fix) We need a 4.41 fix in 3m (high fix)" (November 22, 2005, Senior Trader in New York to Trader in London); 2) "You need to take a close look at the reset ladder. We need 3M to stay low for the next 3 sets and then I think that we will be completely out of our 3M position. Then it's on. [Submitter] has to go crazy with raising 3M Libor." (February 1,2006, Trader in New York to Trader in London); 3) "Your annoying colleague again...Would love to get a high 1m Also if poss a low 3m ... if poss... thanks" (February 3, 2006, Trader in London to Submitter); 4) "This is the [book's] risk. We need low 1M and 3M libor. PIs ask [submitter] to get 1M set to 82. That would help a lot" (March 27,2006, Trader in New York to Trader in London). 5) "We have another big fixing tom[orrow] and with the market move I was hoping we could set the 1M and 3M Libors as high as possible" (May 31, 2006, Trader in New York to Submitter); http://www.cftc.gov/ucm/groups/public/@lrenforcementactions/documents/legalpleading/enfbarclaysorder062712.pdf

[13] See United Kingdom Financial Conduct Authority (2012).

determine the benchmark, and by broadening the set of instruments or types of trades that are used. Specific recommendations for broadening the data collected to fix benchmarks have been made for both the IBORs[14] and for the FX benchmarks.[15]

A key tradeoff is that broadening the data collected to fix a benchmark can increase the heterogeneity of the proxies used for the item being measured, whether through timing or quality differences. Such heterogeneity can be mitigated with statistical methods, but in the end there is the risk of having a benchmark that is more robust to manipulation but not very specific to the trading interests of market participants. One way to do better is to strategically weight the data so as to produce a fixing that efficiently trades off the incentive to manipulate against measurement error. For example, smaller trades (those whose prices are most easily distorted) can be downweighted.[16]

3. Reforming LIBOR

A. How is LIBOR used?

With this general framework in mind, we now turn to the specific problem of reforming LIBOR. Most of the issues that we will discuss pertain to all of the LIBOR currencies—US dollar, British pound, Euro, Swiss Franc and Yen—as well as to the other IBORs, namely EURIBOR and TIBOR. For concreteness, we focus on the case of US dollar LIBOR.

[14] See Market Participants Group on Reference Rate Reform (2014), and Official Sector Steering Group (2014). On widening the time window for LIBOR fixing, see Duffie, Skeie, and Vickery (2013).

[15] See Foreign Exchange Benchmark Group (2014).

[16] This is one of the properties of the theoretical solution provided by Duffie and Dworczak (2014), based on a model in which manipulators, given the chosen weights, maximize their expected trading profits, net of manipulation costs.

Table 1 presents some basic facts concerning the major applications of USD LIBOR.[17] The table covers four broad categories of financial instruments: loans, bonds, securitizations, and derivatives—both over-the-counter (OTC) and exchange-traded (ETD). Several points stand out. First, across a range of applications, the majority of contracts tend to be linked to either the one-month or three-month LIBOR rate. Second, LIBOR is the dominant interest-rate benchmark for trillions of dollars of conventional loans, many of which are retained on the balance sheets of banks and other intermediaries. For example, 97% of the $3.4 trillion syndicated loan market is tied to LIBOR. Among non-syndicated business loans and commercial real estate (CRE) loans, which collectively add up to nearly $6.5 trillion, somewhere between 30% and 50% are linked to LIBOR. And of the $9.6 trillion of non-securitized residential mortgages, about 15% are adjustable-rate and LIBOR-based.

For these on-balance-sheet lending applications, it is easy to understand the appeal of an interest-rate benchmark like LIBOR that embeds an element of bank credit risk. If a commercial bank makes a long-term floating-rate business loan or commercial real estate loan, and funds the loan by borrowing short-term in the wholesale unsecured market, the bank's funding costs are exposed to movements in both the general level of interest rates as well as the bank's credit spreads. Thus if the floating-rate loan is tied to an index based on a riskless rate, for example the T-bill rate, then the bank has hedged only the component of its funding costs that is related to riskless rate. If bank credit spreads widen *relative to the riskless rate*, the bank's net interest margin will suffer. Indeed, during the 2007-2009 crisis, LIBOR rates went up several percent, whereas Treasury rates declined! If the floating-rate loan is instead linked to LIBOR, then the bank will also be hedged with respect to the market-wide component of bank credit spreads,

[17] These facts are drawn from Market Participants Group on Reference Rate Reform (2014).

albeit not to idiosyncratic movements in its own credit spread. As discussed earlier, this on-balance-sheet hedging motive helps to explain why early efforts at creating interest-rate benchmarks in the 1970s gravitated toward a rate like LIBOR that was intended to capture bank credit risk.

As sizable and important as these on-balance-sheet lending applications are, the most striking fact in Table 1 is how they are now utterly dwarfed by trade in interest-rate derivatives tied to LIBOR. For example, the dollar-based OTC interest-rate swap market alone is estimated to be on the order of $107 trillion in gross notional value, 65% of which is linked to LIBOR. Most of that, moreover, is at one tenor of LIBOR, namely three months. Roughly another $100 trillion in interest-rate derivatives, including futures, cross-currency swaps, options (both OTC and exchange-traded), are heavily LIBOR-dependent.

In contrast to the use of LIBOR for hedging a bank's loan funding costs, it is improbable that many users of interest-rate derivatives have an intrinsic economic reason to be exposed to changes in bank credit spreads, or to use these instruments to hedge bank credit spreads. Rather, the majority are likely using these derivatives either to hedge an exposure to the general level of interest rates, to make a speculative bet on market-wide rates, or to intermediate such trades. For these "rates traders," the fact that LIBOR incorporates a bank credit risk component is, if anything, a bit of a nuisance. This inconvenience is apparently more than offset by the liquidity advantages of trading in the tremendously deep LIBOR market, as discussed in Section 2.B.

B. Costs of excessive agglomeration around the LIBOR benchmark

In the narrative that we have in mind, bank-hedging motives were the seed that originally made LIBOR an attractive benchmark. From this seed, and given the strong agglomeration effects associated with liquidity and transparency externalities, the market for interest-rate-linked

products has grown exponentially and has tended to remain "stuck" on LIBOR. This is so despite the fact that much of the subsequent demand for referencing an interest-rate benchmark has come from users—most notably derivatives traders—who care a great deal about liquidity and transparency but who may have no particular desire for exposure to the bank-credit-risk component of LIBOR.

If this story is correct, it suggests that there are two distinct costs associated with the pileup of so much trading on LIBOR-linked contracts. First, LIBOR may offer a less-than-ideal fit for the purposes of the majority of derivatives users. Liquidity externalities can create coordination failures and Pareto-dominated equilibria. That is, even if most derivatives users would prefer to have their contracts tied to another benchmark without a bank credit risk component (for example, T-bills), once LIBOR has become the dominant benchmark, it is very difficult for the market to switch to this new equilibrium benchmark choice on its own.

Second, the incentives for market manipulation are heightened when there is such a large derivatives market indexed to a rate that is set in a primary market where trading activity is orders of magnitude smaller. What is striking about many of the documented cases of LIBOR manipulation is that they involved only very small rate distortions, with the guilty parties often misstating their borrowing costs by just one or two basis points. Even such tiny distortions in LIBOR fixings can be potentially very profitable for a manipulator, to the extent that he has accumulated a large enough position in derivatives whose payments are contractually based on the LIBOR fixing. Thus the relative scales of the two markets—the derivatives market versus the primary market which ultimately determines the reference rate—play a key role in manipulation incentives.

Moreover, this manipulation problem is not resolved merely by improving the design of the LIBOR fixing methodology, despite the importance of making these improvements. In the past, manipulators arranged for dishonest judgment-based reports of bank borrowing rates. But even with a fully transactions-based benchmark, a manipulator might attempt to distort actual transactions in the underlying bank funding markets. A thin underlying borrowing market cannot be expected to provide a robust foundation for a multi-hundred-trillion dollar derivatives market, even with substantial improvements to the LIBOR fixing methodology.

C. A two-rate approach

i. The basic idea

If we were to start from scratch, what might a more efficient and resilient set of arrangements for interest-rate benchmarking look like? The above discussion suggests that there could be considerable appeal in a "two-rate approach," that is, two distinct types of interest-rate benchmarks.[18] One of these, an improved version of LIBOR itself, would continue to be based on banks' wholesale unsecured funding costs, and would be appropriate for applications that rest on that credit risk component, such as hedging the revenues of balance-sheet lenders. This banking-oriented benchmark would be reformed so as to be transactions-based and subject to a tougher monitoring regime, and hence less subject to manipulation. We call this improved version of the bank-based rate "LIBOR+." We will describe a bit later how LIBOR+ might be implemented.

The second benchmark would be based on a riskless or near-riskless rate that is established in a broad and deep market. The goal here would be to give pure rates traders—potentially a large fraction of the derivatives market—something that fits their risk-transfer needs well, while at the same time reducing the manipulation incentives that arise when so much rates-

[18] Powell (2014) outlines a similar argument.

trading is tied to a rate like LIBOR that is based on the much thinner underlying market for unsecured bank borrowing.

For the two-rate approach to be more fully articulated, three sets of questions need to be addressed. First, how does one most effectively design LIBOR+ so that it is based to the maximum extent possible on actual market transactions, rather than on banks' discretionary reports of their funding costs? Second, what is the appropriate riskless or near-riskless rate to use for pure rates-trading applications? Third, and perhaps most challenging, given that we are not actually starting from scratch, and given the large obstacles posed both by legacy contracts and liquidity-driven coordination problems, how can policymakers help to break the stranglehold of existing LIBOR and pave the way for transition to a two-rate regime? In what follows, we consider each of these questions in turn.

ii. The design of LIBOR+

The various policymaking groups that have studied the manipulation problems associated with LIBOR have all concluded that it would be desirable to move away from the current practice of fixing LIBOR rates based on judgmental submissions from a panel of banks, and move to a fixing methodology that is more anchored in observable, verifiable market transactions. In addition to whatever benefits such a switch might bring in terms of reduced manipulability, if the fixing methodology is made entirely algorithmic, it would also eliminate a potential threat to financial stability—namely that, because of legal risks, member banks might decide to defect from the LIBOR panels, making it impossible to calculate a reliable reference rate under the poll-based methodology. In the case of EURIBOR, there has already been a notable exodus from the panel of reporting banks, which had dropped from a high of 44 to only

26 banks by June 2014.[19] With an algorithmic approach to fixing, there is no need for banks to voluntarily contribute to a LIBOR panel.

Although a transactions-based approach has clear appeal, it is more difficult to implement than one might first think. For example, three-month LIBOR is meant to reflect the typical rate at which large banks borrow, on an unsecured basis, for a three-month term, *from other banks*. But the volume of borrowing in the interbank market is small, and has been secularly trending downward. Some of the secular decline in interbank borrowing is likely due to the extraordinary monetary policies of the last several years, which have left banks glutted with reserves and therefore less dependent on interbank borrowing to manage their liquidity positions. There is also a significant reduction in interbank unsecured borrowing during periods of market stress. This tendency is especially pronounced at longer maturities, as explained by Gorton, Metrick and Xie (2014).[20] The paucity of interbank lending is especially severe in Japanese Yen and Swiss Francs, as documented by the report of the Market Participants Group on Reference Rate Reform (2014), henceforth called the "MPG Report."

Simply put, most banks don't borrow at longer maturities from other banks on most days. This is an obvious challenge to any attempt to measure term interbank borrowing rates on a daily basis, be it judgment-based or transactions-based. In order for LIBOR to serve as an effective benchmark, its fixing must be broadened so as to be based on unsecured bank borrowings *from all wholesale sources*—not just other banks, but non-bank investors in bank commercial paper and large-denomination CDs. This is a key recommendation for LIBOR+ in the MPG Report.

Indeed, the MPG conducted a pilot study of LIBOR+, using proprietary data from a unit of J.P. Morgan that covers approximately 40% to 45% of the overall market for unsecured bank

[19] See Brundsen (2014).

[20] See Gorton, Metrick, and Xie (2014).

borrowing. Table 2 gives some details on the density of transactions at various tenors in this data set. For example, over the period from 2011 to early 2014, there were roughly 25 to 30 transactions at the three-month tenor on a typical day, for an average total daily dollar volume of about $1 billion. Unfortunately, on the lowest-volume days, there were only a handful of transactions, numbering on the order of 3 to 8.

With these data in hand, the MPG built a prototype LIBOR+ fixing algorithm. Their basic methodology is as follows. On any given day *t*, for any given bank *i*, and for any tenor of interest, if bank *i* has an available transaction, the rate on that transaction is entered with a weight of unity into the index. If bank *i* does not have an available transaction, the algorithm goes back to the nearest prior date *t-k* when there is a transaction, and enters the rate on that transaction into the index with a reduced weight—one that gets smaller as the distance *k* from the present gets larger. Thus the algorithm includes non-contemporaneous data to compensate for the low density of transactions on any given day, but downweights the older data in light of its staleness.[21]

The results of this exercise are plotted in Figure 1, which compares the MPG's LIBOR+ construct to actual LIBOR for each of the one, three and six month tenors. As can be seen, while LIBOR+ is always more volatile on a day-to-day basis than LIBOR—which is not surprising given the opinion-based nature of LIBOR—the levels of the two time series track each other reasonably closely at both the one-month and three-month tenors. At the six-month tenor, the fit is considerably less good.[22] Given that the vast majority of contracts in dollar LIBOR reference the one and three-month tenors, the LIBOR+ methodology holds considerable practical promise,

[21] This approach was proposed by Duffie, Skeie, and Vickrey (2013).

[22] Some of this deterioration in fit is due to the paucity of transactions at six-month term. But some of it is due to a particular form of sample selection—the fact that during a period of market stress, only the highest credit-quality banks are able to issue at a six-month maturity. This selection effect tends to make the transactions based LIBOR+ lower than the judgmentally-reported LIBOR at such times.

especially if the data supporting it can eventually be augmented to capture the entire universe of CD and CP transactions.

However, even if a transactions-based LIBOR+ methodology can be made to work well from an economic perspective, there remains the crucial question of whether it also "works" legally. In other words, for the large stock of existing legacy contracts that reference LIBOR, is it possible to seamlessly substitute a fixing along the lines of LIBOR+ without causing private litigants to challenge this substitution? We will return to this question later.

iii. What is a suitable riskless benchmark?

Despite the potential promise of LIBOR+, we believe that it would be a mistake for such a benchmark to shoulder the burden of being the primary reference rate for the entire interest-rate derivatives market. This point is underscored by a comparison of the magnitudes in Tables 1 and 2. At the commonly-used three-month tenor, transactions in the underlying market for unsecured bank funding are roughly on the order of a billion dollars on a typical day, while the volume of gross notional outstanding in the swap market that references LIBOR at this tenor is on the order of $100 trillion, or *100,000 times larger*.[23] As we have been emphasizing throughout, this divergence leaves a strong incentive for a trader with a large derivatives position to manipulate even a transactions-based LIBOR+, for example by borrowing or lending (or by arranging for someone else to borrow or lend) more or less aggressively in the CP or CD market.

[23] This compares a flow with a stock, but the difference remains striking. The daily volume of USD Libor-based derivatives has an order of magnitude of around 1.15 trillion USD, according to BIS Triennial data, at Table 3 of Bank for International Settlements (2013). This is roughly a factor of 1000 times the volume of trade determining 3-month USD LIBOR. Moreover, payments on the much larger stock of outstanding derivatives are exposed to daily LIBOR fixings.

In our view, a key to the reform process is therefore an effort to encourage the transition of a large fraction of derivatives trading to a robust risk-free or nearly risk-free rate. We next consider several candidates for such a rate.

Central-bank administered rates

One potentially elegant approach would be to have derivatives contracts reference a rate that is directly administered by the Federal Reserve. One of these, the interest rate paid by the Fed to banks on their excess reserves, is known as IOER. The other, known as RRP, is the rate paid by the Fed to a wider range of market participants on overnight reverse repurchase agreements. Because these rates are administered by the Fed, as opposed to being set in the market, they are immune from manipulation. If market participants were induced to use these central-bank rates as benchmarks, the manipulation problem could be dramatically reduced.

A hitch is that the appeal to market participants of using these administered rates will depend on the details of how the Fed uses these rates to implement monetary policy. At one extreme, if the Fed decides to leave a large spread between IOER and RRP, then market-determined short-term rates are likely to bounce around in a range between these two administered rates. In that case, neither of the two rates would be a tight proxy for the market risk that investors are most anxious to transfer. At the other extreme, as the IOER rate and the RRP rate approach one another, they both become closer to market rates and presumably more attractive as a benchmark for investors. However, it may not make sense to design a monetary policy operating regime in order to solve the reference-rate problem—particularly if doing so would make it much harder to alter the monetary policy regime at some later date. A secondary concern is whether an overnight rate would be attractive as a reference rate for the settlement of floating-rate contracts based on longer coupon maturities such as three months.

T-bill rates

The rate on short-term T-bills is another natural candidate for a riskless reference rate. While this market is not manipulation-proof, it is certainly much deeper and more active than the market for unsecured bank borrowing. Moreover, in January 2014 the U.S. Treasury began to issue floating-rate notes linked to auction-determined rates on 13-week T-bills. The Treasury's presence in the floating-rate note market may help to boost liquidity in contracts that reference T-bill rates.

The MPG received input from a wide range of market participants regarding their desire to use T-bill rates as a reference rate for derivatives contracts. The response indicated a general lack of enthusiasm for this option. One reason for this skepticism is that during periods of market stress, "flight-to-quality" or "safe-haven" demands tend to lower the rates on T-bills relative to those on other relatively safe instruments. This phenomenon is illustrated in Figure 2, which plots the rate on 3-month T-bills along with the 3-month OIS rate, another often-used proxy for a near-riskless rate, as well as 3-month LIBOR.[24] Several downward spikes of the bills rate relative to OIS during the financial crisis are readily apparent. To the extent that investors are seeking to hedge or speculate on the general level of rates without taking a view on movements in these T-bill-specific safe-haven premiums, these sorts of spikes can make T-bills less appealing as a reference rate.

Nevertheless, we think it is easy to exaggerate this concern. Over the sample period December 2001 to July 2013 shown in Figure 2, the correlation between 3-month T-bill rates and

[24] The 3-month OIS rate is the rate on a so-called overnight index swap, which pays a pre-determined fixed rate in exchange for receiving the realized geometric mean of the federal funds rate over the 3-month term of the contract. Thus the 3-month OIS rate can be thought of as the market's expectation for the average federal funds rate that will prevail over the upcoming three months. To the extent that fed fund transactions—which are overnight unsecured borrowings by banks—are themselves close to riskless, the 3-month OIS rate is a reasonable proxy for a 3-month riskless rate, but one that does not incorporate the same kind of safe-haven premium as T-bills.

3-month OIS rates is 0.995 in levels and 0.560 in weekly changes. The basis risk here is notable mainly in tail events. Given the other obvious merits of using T-bills as a reference rate, our view is that this option should be given careful consideration.

General-collateral repo rates

Another near-riskless rate is the so-called Treasury general collateral repo (GC repo) rate. This is the rate at which dealers obtain overnight financing secured by treasury securities. This market is highly liquid; recently, about $590 billion of treasuries are financed this way on a typical day.[25] Hence, like T-bill rates, one would expect GC repo rates to be relatively robust to manipulation.

Although there is currently no official GC repo rate, Figure 3 plots a close proxy, the General Collateral Finance (or "GCF") rate.[26] As shown, GC repo rates, like T-bill rates, tend to spike downward during periods of market stress, reflecting a safe-haven property. Some of the volatility of the GC repo rate is also due to the one-day maturity of this rate. That is, unlike the 3-month bill rate, there is no "averaging out" of the impact of short-lived supply and demand shocks.

Overnight index swap (OIS) rates

We have already briefly mentioned the overnight index swap (OIS) rate as another candidate low-risk rate. By entering an OIS position as a fixed-rate payer, one agrees to pay at maturity in T days the notional principal amount plus interest on this amount at the contractually

[25] The Federal Reserve Bank of New York provides the amounts of securities financed in the tri-party repo market on the seventh business day of each month. See http://www.newyorkfed.org/banking/pdf/jul14_tpr_stats.pdf

[26] The data in the figure is for the Treasury General Collateral Finance (GCF) rate, which is published by the Depository Trust and Clearing Corporation. The GCF rate is based on a subset of transactions (approximately 20%) in the broader tri-party GC repo market.

agreed OIS rate R, in exchange for a floating-rate payment from the counterparty. The floating-rate payment per dollar of notional is the compounded overnight amount, that is, $(1+ r_1)(1 + r_2)\ldots(1 + r_{T-1})$, where r_k is the stipulated benchmark overnight interest rate on day k. For the US-dollar OIS market, the standard overnight benchmark rate currently used for this purpose is the Federal Funds Effective Rate (FFER). In most other currencies, a general collateral repo rate is the overnight benchmark rate used for the settlement of OIS contracts.

The potential appeal of the OIS rate as a standardized low-risk rate is evident in Figure 2. During periods of market stress, there are no upward spikes associated with jumps in term credit risk premiums, and no downward spikes associated with flight to a Treasury-like safe haven. Some researchers and many market practitioners therefore rely on OIS rates as a relatively clean and transparent proxy for the "true" riskless rate.

However, it is less clear that the OIS rate is ready for the more demanding task of determining the payments on many trillions of dollars of interest-rate derivatives. One concern is the dependence of US-dollar OIS contracts on the overnight federal funds rate. Partly because of changes in monetary policy, trading in the overnight federal funds market has been thin and sometimes not reflective of typical overnight bank borrowing rates. An alternative that has been mooted is to change the overnight rate referenced in OIS contracts from FFER to the general collateral repo rate.[27] More importantly, the OIS market itself is a derivatives market that is not yet heavily traded. For example, Fleming, Jackson, Sarkar, Li, and Sobel (2012) report that between June and August 2010 there were an average of 31 transactions a day in USD OIS, representing a notional volume of about $30 billion, versus an average of 609 trades per day in

[27] This substitution option was raised in the MPG Report, and was further discussed by a governor of the Federal Reserve and by the Chairman of ISDA. See Rennison (2014).

Libor-based swaps representing a notional volume of $86 billion.[28] It is not clear that one should attempt to shift volume from LIBOR on the premise that the underlying bank-borrowing market is so thin, and then substitute LIBOR with another rate such as OIS that is also set in a relatively thinly traded market.

A more novel benchmark design discussed in the MPG Report is a reference rate for terms such as three months that is obtained directly by compounding overnight rates over the three months leading up to settlement date. For example, the contractually agreed floating-rate payment due at the end of a 90-day contract period would be $P = (1+ r_1)(1 + r_2)\ldots(1 + r_{T-1})$, where $T = 90$ and where r_k is the stipulated benchmark overnight interest rate on day k of the contract period, for example the overnight GC Repo rate. The associated effective interest rate, called "OIR," is simply P-1. This OIR rate is clearly a feasible and implementable benchmark. It is extremely robust to manipulation because, as we have discussed, the underlying GC Repo rate is itself robust, and the averaging inherent in the OIR formula makes manipulation all the more difficult. The one potential drawback of the OIR rate is its "backward-looking" nature. While some market participants might prefer to know their next floating-rate interest payment well in advance of the due date rather than waiting until very shortly before the payment is due, this wait-and-see payment method is not uncommon to most wholesale market participants such as swaps traders. Even retail financial consumers are familiar with the idea of having their latest floating-rate mortgage payments reported to them after the fact in their bank statements, in the same manner as their utility payments.

None of the alternative reference rates that we have discussed is perfect for all applications, but they are feasible and relatively effective substitutes for many applications

[28] See Fleming, Jackson, Li, Sarkar, and Zobel (2012).

currently served by LIBOR. These alternative rates do not include a component for bank credit risk, which is an advantage over LIBOR for most "rates trading" applications. All of these alternatives, with the exception of the OIS rate (whose market is currently relatively thin), are far less subject to manipulation than LIBOR. If the OIS market were to grow sufficiently, perhaps boosted by support from the official sector, it too might someday become an effective substitute for a significant amount of LIBOR-based derivatives trading, though in our judgment it is not currently up to the task.

4. Can We Get There from Here? Transition Challenges

To summarize the discussion thus far: we have argued that if we could start the world from scratch, we would aim for a two-rate model, with a transactions-based LIBOR+ serving as the reference rate for most on-balance-sheet lending contracts, and with some low-credit-risk reference rate (such as the T-bill rate, the OIR rate, or perhaps eventually the OIS rate) serving as the reference rate for the majority of interest-rate derivatives. However, given the large stock of legacy contracts that are already tied to LIBOR, as well as the strong liquidity-driven network effects that we have discussed, getting from here to there presents a formidable set of challenges. In what follows, we lay out a transition strategy that we think has the best shot of addressing these challenges. We acknowledge, however, that even this best-case strategy faces a number of daunting uncertainties.

A. *A "seamless" transition from LIBOR to LIBOR+ for legacy contracts*

The first element in our idealized transition strategy is a "seamless" transition from LIBOR to LIBOR+ for legacy contracts. Simply put, at some future date, the LIBOR administrator would stop publishing LIBOR based on its current fixing methodology, and would

begin publishing LIBOR+ in its place.[29] Contracts would not need to be re-written to change the stated "LIBOR" reference rate; merely the fixing would change.

The key risk associated with this approach is that it may provoke legal challenges, whereby one party to a contract claims that his obligations should be discharged based on the doctrine of "contract frustration." The MPG Report contains a detailed analysis of this issue. Although it is hard to be definitive, the MPG suggests that contract-frustration risks are likely to be mitigated when: (i) the conceptual basis for LIBOR+ (as a rate representative of unsecured bank borrowing costs) is very close to that for existing LIBOR; and (ii) when the two rates have similar levels as of the transition date, as well as similar statistical properties, thereby minimizing any value reallocation associated with the switch. The MPG concludes, based on legal consultation as well as the sort of pilot-testing of LIBOR+ shown in Figure 1, that a "seamless transition can be achieved for USD LIBOR at the popular one-month and three-month tenors without raising undue risk of legal contractual frustration risk." (page 25).[30]

B. *Pushing newly-written derivatives to a riskless reference rate*

While a seamless transition appears to be a promising approach for moving contracts from LIBOR to LIBOR+, it is unlikely to be viable for moving contracts from LIBOR to an alternative low-credit-risk rate of the sort we have in mind, such as T-bills or OIR. The differences between LIBOR and these alternatives are too substantial, both in concept and in statistical behavior, for such a switch to avoid legal challenges based on contract frustration. Instead, if the goal is to move a major fraction of derivatives trades to a riskless rate, this must be accomplished differently. We propose the following set of steps.

[29] The current administrator for LIBOR is ICE Benchmark Administration, which took over from the British Bankers' Association (BBA) in early 2014.

[30] The MPG Report does not reach a final conclusion about whether to transition from LIBOR to LIBOR+at the somewhat less popular 6-month maturity.

First, the majority of already-existing derivatives contracts would not be altered, but rather could simply be allowed to roll off over time. An analysis of the maturity distribution of these contracts suggests that a substantial "roll-off" can occur over a five-year horizon. Specifically, for the different categories of OTC and exchange-traded derivatives displayed in Table 1, about 65% of OTC interest-rate swaps will roll off over five years, as would approximately 100% of floating-rate agreements, 74% of OTC interest-rate options, 76% of cross-currency swaps, 100% of exchange-traded interest-rate options, and 99% of exchange-traded interest-rate futures.[31]

Second, regulators would use a variety of tools to encourage newly-written derivatives contracts to reference a riskless rate such as T-bills or OIR, rather than LIBOR (or LIBOR+). For example, bank regulators could, for the firms that fall under their authority, increase the effective capital charges that apply to LIBOR-based derivatives. In addition to mitigating manipulation incentives, we believe that there is a legitimate safety-and-soundness rationale for doing so. As noted above, the survey-based nature of current LIBOR creates the risk of defections from the bank panels, with the attendant dangers of market-wide disruptions if the LIBOR rate cannot be produced. To the extent that a transition from LIBOR to LIBOR+ takes a long time or is subject to uncertainty, beginning the process of moving derivatives to an alternative reference rate would have the added benefit of reducing this type of risk to financial stability.

It is difficult to say just how much regulatory force would need to be applied to substantially change contracting practices in the derivatives market, or how much force it would be normatively appropriate to apply. On the one hand, as we have argued above, there are

[31] These facts are drawn from the table on page 309 of the MPG Report.

elements of a pure coordination problem here. It may well be that many derivatives users would actually prefer to be in an equilibrium in which there were highly liquid contracts that referenced a riskless rate as opposed to one with a significant component of bank credit risk. In this case, a strong regulatory hand that pushes the outcome towards this new equilibrium would be seen as socially desirable. On the other hand, there is undoubtedly significant heterogeneity among derivatives users, and it is far from clear that all would prefer the new equilibrium. This suggests that any strong push by regulators would likely create losers as well as winners, and cuts against an overly aggressive use of regulatory authority such as a highly punitive capital charge on derivatives that remain linked to LIBOR or LIBOR+. Striking the right balance on this dimension seems to us to be one of the most challenging aspects of the reform process.

5. Conclusions

Rather than restating our arguments, we close by highlighting a fundamental limitation of our analytical approach. From the outset, we have taken as given two policy objectives: (i) that it is desirable to maintain large, deep, and liquid interest-rate derivatives markets; and (ii) that is also desirable to design markets in a way that leans against manipulation. But as we have seen, there is a fundamental tension between these two objectives: the deeper and more liquid a derivatives market becomes, the more tempting it is for market participants to manipulate the underlying benchmark referenced by these derivatives.

This observation suggests that even the best market design can only go so far, and that if one wishes to support the existence of a very large derivatives market, some equilibrium level of manipulation may be an inevitable cost of doing business. This is an uncomfortable prospect for policymakers to acknowledge, but it is nevertheless important to be candid on this score. The last

thing one wants to do is embark on a costly and time-consuming set of reforms while over-promising what they can deliver. On a more constructive note, acknowledging the limits of market design policies such as those that we have put forth underscores the need for a complementary attack on the manipulation problem from a legal (rules and enforcement) angle. Simply put, given that one can't count on market design as a panacea, vigorous enforcement of the civil and criminal statutes against market manipulation will continue to play an important role no matter what other reforms are undertaken.

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Table 1:
USD LIBOR Market Footprint by Asset Class and Tenor[32]

Asset class		Volume ($B)	% LIBOR-related	Most Common Tenors
Loans	Syndicated loans	~3,400	97%	1m and 3m
	Corporate business loans	1,650	30-50%	1m and 3m
	Non-corporate business	1,252	30–50%	1m and 3m
	CRE/Commercial mortgages	3,583	30–50%	3m
	Retail mortgages	9,608	15%	6m
	Credit cards	846	Low	
	Auto loans	810	Low	
	Consumer loans	139	Low	
	Student loans	1,131	7%	1m and 3m
Bonds	Floating/Variable Rate Notes	1,470	84%	1m and 3m
Securitizations	RMBS	~7,500	24%	1m (83%)
	CMBS	~636	4%	1m (75%)
	ABS	~1,400	37%	1m (76%)
	CLO	~300	71%	3m (82%)
OTC Derivatives	IR Swaps	106,681	65%	3m (90%)
	FRAs	29,044	65%	3m (90%)
	IR Options	12,950	65%	3m (90%)
	X-currency swaps	22,471	65%	3m (90%)
ETD Derivatives	IR Options	20,600	98%	3m
	IR Futures	12,297	82%	3m

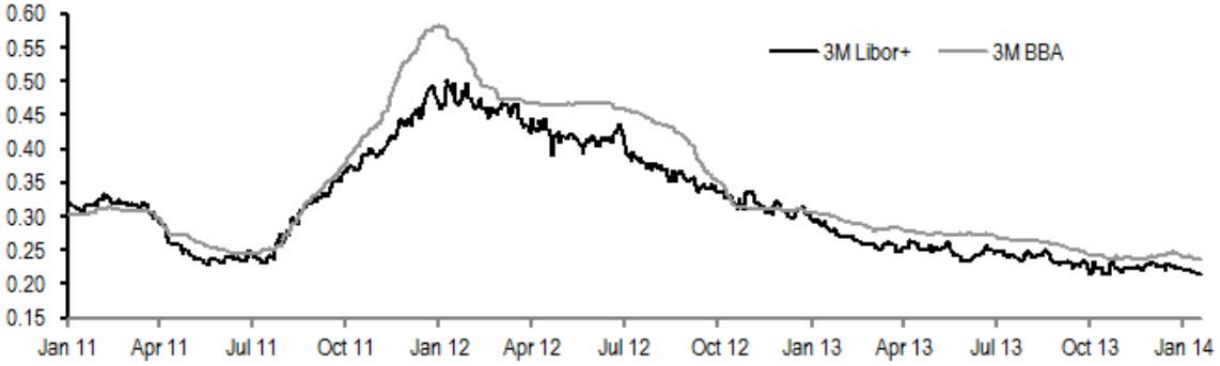
[32] This table is adapted from *Market Participants Group on Reference Rate Reform, Final Report*, March 2014.

Table 2:
Availability of Transactions Data on Unsecured Bank Borrowing

		Number of Trades					Number of Issuers					Volume ($mn)				
		O/N	1W	1M	3M	6M	O/N	1W	1M	3M	6M	O/N	1W	1M	3M	6M
Daily Avg	2014	468	74	21	19	18	15	9	7	8	7	20,223	3,204	888	706	718
	2013	511	95	18	25	13	16	9	6	8	6	22,312	4,157	702	1,006	474
	2012	344	62	24	31	13	17	10	8	9	5	14,889	2,637	888	1,211	452
	2011	435	79	38	34	18	21	15	14	11	5	18,945	3,356	1,407	1,331	706
Daily Max	2014	538	127	42	45	40	17	13	10	12	11	23,853	5,460	1,869	1,903	1,861
	2013	878	280	78	126	76	20	18	13	17	15	39,722	13,043	3,479	5,904	2,892
	2012	521	225	80	112	55	24	20	19	19	13	22,985	10,007	3,613	4,539	2,140
	2011	666	263	113	107	112	27	25	32	24	15	30,015	11,686	4,982	4,642	4,985
Daily Min	2014	406	31	3	8	2	14	5	3	4	2	16,998	1,279	77	222	50
	2013	187	7	1	1	1	13	3	1	1	1	6,910	204	5	1	1
	2012	33	4	0	2	0	7	2	0	1	0	1,399	124	0	64	0
	2011	235	10	3	3	0	17	4	1	1	0	9,608	242	75	24	0

Note: this table displays daily average, maxima and minima for number of trades, number of issuers and dollar volume of unsecured bank borrowing transactions in the commercial paper (CP) and certificate-of-deposit (CD) markets based on a sample from a unit of J.P. Morgan over the period 2011 through January 2014. Maturity buckets are defined as follows: O/N=1day to 4days, 1W=6days to 8days, 1M=28days to32days, 3M=85days to 95days, 6M=175days to 185days. Source: *Market Participants Group on Reference Rate Report, Final Report*, March 2014.

Figure 1:
Comparison of MPG's Transaction-Based LIBOR+ to BBA LIBOR



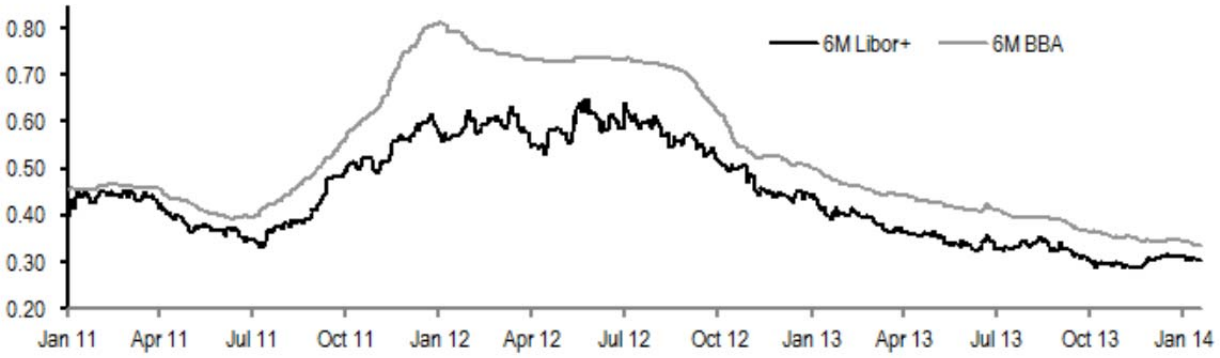


Figure 2:
3-Month LIBOR, OIS and T-Bills [Data source: Bloomberg.]

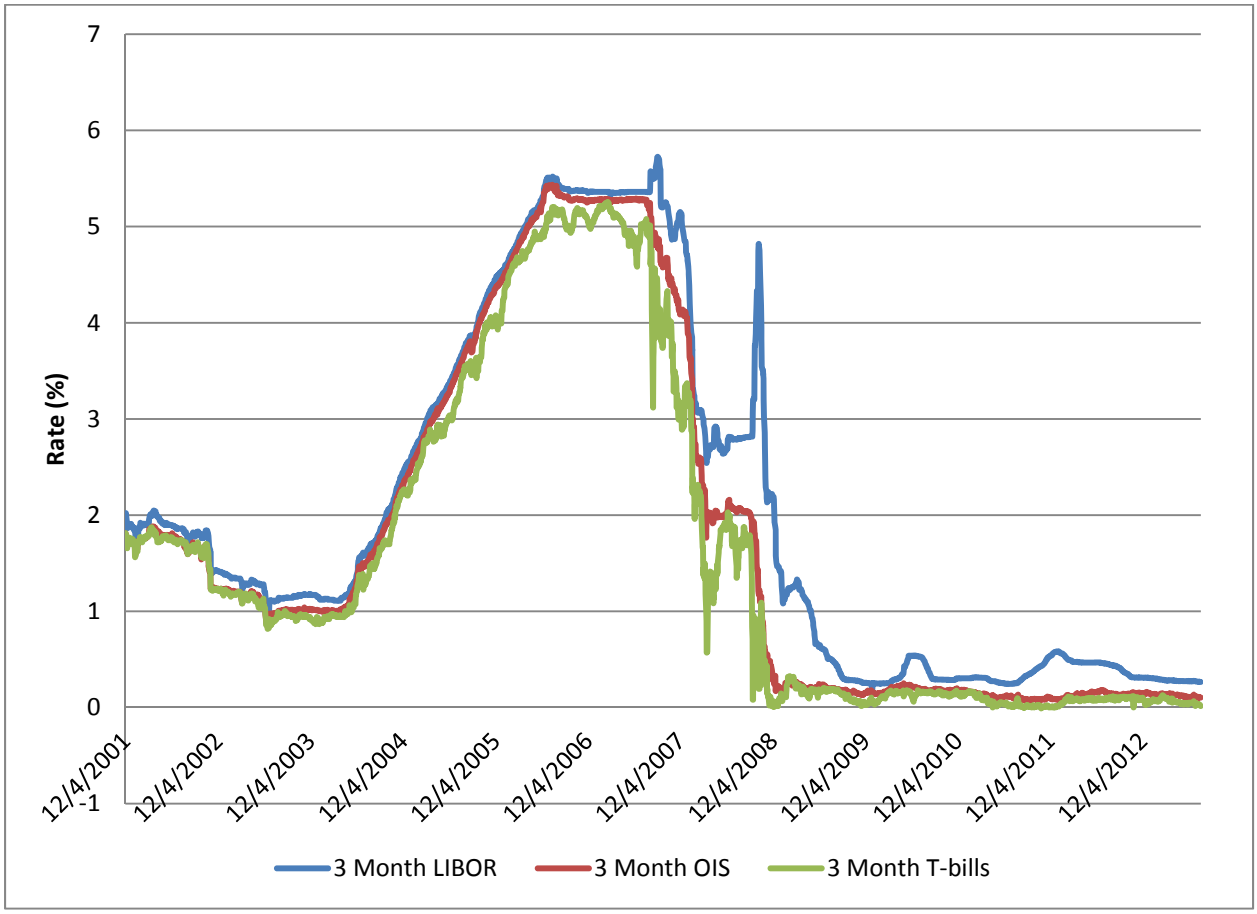


Figure 3:
Overnight Treasury General Collateral Repo Rate [Data source: Bloomberg.]